(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 March 2003 (06.03.2003)

PCT

(10) International Publication Number
WO 03/018882 A1

(51) International Patent Classification[7]: C30B 13/00

(21) International Application Number: PCT/US02/27246

(22) International Filing Date: 27 August 2002 (27.08.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/315,181 27 August 2001 (27.08.2001) US

(71) Applicant (*for all designated States except US*): **THE TRUSTEES OF COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK** [US/US]; 116th Street and Broadway, New York, NY 10027 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **IM, James, S.** [US/US]; 520 W. 114th Street, Apt. 74, New York, NY 10027 (US). **VAN DER WILT, Paul, Christiaan** [NL/NL]; Oostavenstraat 2A, NL-2312 Leiden MB (NL).

(74) Agents: **TANG, Henry** et al.; Baker Botts L.L.P., 30 Rockefeller Plaza, New York, NY 10112-4498 (US).

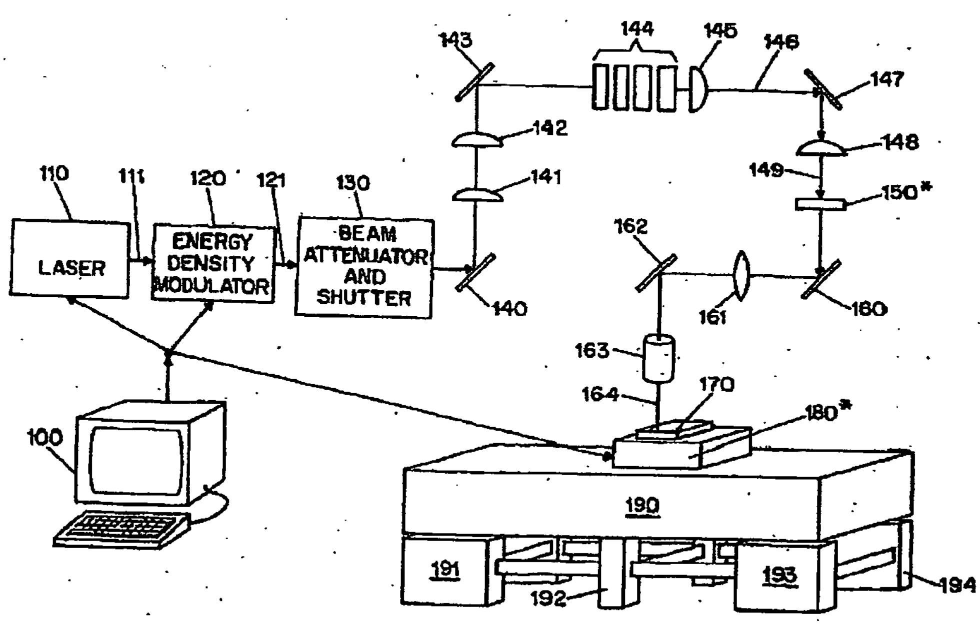
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: IMPROVED POLYCRYSTALLINE TFT UNIFORMITY THROUGH MICROSTRUCTURE MIS-ALIGNMENT



(57) Abstract: Methods of making a polycrystalline silicon thin-film transistor having a uniform microstructure. One exemplary method requires receiving a polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction, and placing at least portions (410, 420) of one or more thin-film transistors on the received film such that they are tilted relative to the periodic structure of the thin film.

WO 03/018882 A1

A METHOD TO INCREASE DEVICE-TO-DEVICE UNIFORMITY FOR POLYCRYSTALLINE THIN-FILM TRANSISTORS BY DELIBERATELY MIS-ALIGNING THE MICROSTRUCTURE RELATIVE TO THE CHANNEL REGION

SPECIFICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on United States provisional patent application serial no. 60/315,181, filed August 27, 2001, which is incorporated herein by reference for all purposes and from which priority is claimed.

BACKGROUND OF THE INVENTION

[0002] Technical Field. The present invention relates to semiconductor processing techniques, and more particularly, techniques for fabricating semiconductors suitable for use at thin-film transistor ("TFT") devices.

[0003] Background Art. Semiconductor films, such as silicon films, are known to be used for providing pixels for liquid crystal display devices and organic light emitting diode display devices. Such films are commonly processed via excimer laser annealing ("ELA") methods, where an amorphous silicon film is irradiated by an excimer laser to be crystallized.

[0004] Significant effort has gone into the refinement of "conventional" ELA (also known as line-beam ELA) processes in the attempt to improve the performance of the TFT devices placed on the processed semiconductor thin films. For example, U.S. Patent No. 5,766,989 issued to Maegawa et al., the entire disclosure of which is incorporated herein in its entirety by reference, describes the ELA methods for forming polycrystalline thin film and a method for fabricating a TFT. The '989 patent attempts to address the problem of non-uniformity of characteristics across the substrate, and provide certain options for apparently suppressing such non-uniformities.

[0005] However, the details of the beam-shaping approach used in conventional ELA methods make it extremely difficult to reduce the non-uniformities in the semiconductor films and to improve the performance characteristics of such films. For example, in a low-temperature polycrystalline silicon ("LTPS") process, when the size of the grains becomes

comparable to the dimensions of the channel region of the TFT, large device-to-device non-uniformity results. This is caused by the randomness of the microstructure, i.e., the random location of the grains and thus the grain boundaries. Such non-uniformity, especially when perpendicular to the current flow, can act as a current barrier. Further, when the transistor is in its off-state, carriers are generated at the grain boundary, which contribute to the off-current. This is especially the case when the grain boundary is in or close to the drain–channel junction.

[0006] Therefore, it has been realized that control over the microstructure is needed in order to ensure a uniform TFT process, both with respect to periodicity and location. Regarding the former, the film should be uniform, exhibiting periodicity in the location of the grains and thus the grain boundaries. Regarding the latter, the location of the grains and thus the grain boundaries should be controlled so that their contribution to the electrical characteristics is the same for every single device.

[0007] In an pulsed-laser, e.g., an excimer laser, irradiaton process to obtain LTPS films, control over the TFT microstructure may be obtained through the use lithography to induce such periodicity. The use of lithography also accounts for location control, since the accurate alignment procedure of the lithographic process is used. Unfortunately, the use of lithography requires at lease one extra processing step, which in turn increases complexity and thus costs.

[0008] Alternatively, control over the TFT microstructure may be obtained through the use of sequential lateral solidification ("SLS") techniques. For example, in U.S. Patent No. 6,322,625 issued to Im and U.S. patent application serial no. 09/390,537 (the "'537 application"), which is assigned to the common assignee of the present application, the entire disclosures of which are incorporated herein by reference, particularly advantageous apparatus and methods for growing large grained polycrystalline or single crystal silicon structures using energy-controllable laser pulses and small-scale translation of a silicon sample to implement sequential lateral solidification have been described. As described in these patent documents, at least portions of the semiconductor film on a substrate are irradiated with a suitable radiation pulse to completely melt such portions of the film throughout their thickness. In this manner, when the molten semiconductor material solidifies, a crystalline structure grows into the solidifying portions from selected areas of the semiconductor film which did not undergo a complete melting. Thereafter, the beam pulses irradiate slightly offset from the crystallized areas so that the grain structure extends into the molten areas from the crystallized areas.

[0009] Using the system shown in Fig. 1, an amorphous silicon thin film sample is processed into a single or polycrystalline silicon thin film by generating a plurality of excimer

laser pulses of a predetermined fluence, controllably modulating the fluence of the excimer laser pulses, homogenizing the modulated laser pulses in a predetermined plane, masking portions of the homogenized modulated laser pulses into patterned beamlets, irradiating an amorphous silicon thin film sample with the patterned beamlets to effect melting of portions thereof corresponding to the beamlets, and controllably translating the sample with respect to the patterned beamlets and with respect to the controlled modulation to thereby process the amorphous silicon thin film sample into a single or polycrystalline silicon thin film by sequential translation of the sample relative to the patterned beamlets and irradiation of the sample by patterned beamlets of varying fluence at corresponding sequential locations thereon.

[0010] While the system of Fig. 1 is highly advantageous in generating uniform, high quality polycrystalline silicon and single crystal silicon which exhibit periodicity and thereby solves a problem inherent with conventional ELC techniques, the technique does adequately not account for control over grain boundaries. For example, in the simplest form, SLS requires two pulses to crystallize the amorphous precursor into an LTPS film with partial periodicity, e.g., the 2-shot material shown schematically in Figure 2a. The periodicity is only in one direction, shown by long grain boundaries 210, 220, 230, 240, 250 that are parallel to each other and which also have a protrusion to them. However, the position of the short grain boundaries is not at all controlled. The spacing between the parallel grain boundaries can be increased, and this material is in general called n-shot material. Likewise, Figure 2b shows a so-called 4-shot material in which the grain boundaries are periodic in both directions. Again, the spacing between the grain boundaries can be increased, and is generally referred to as 2n-shot material.

[0011] While SLS techniques offer periodicity, such techniques do not offer accurate control of the location of grain boundaries. Referring to Figures 2c-d, the LTPS film produced includes a varying number of long grain boundaries perpendicular to the current flow, and the possibility of having a perpendicular grain boundary in or out of a TFT drain region. Both problems become more severe when grain size is increasing and/or when channel dimensions are decreasing, i.e., when the size of the grains becomes comparable to the dimensions of the channel region. While there has been a suggestion in United States Patent No. 6,177,301 to Jung to misalign TFT channel regions with respect to the grain growth direction, that suggestion is made without taking into account the underlying need to maintain uniformity in TFT microstructure. Accordingly, there exists a need for a TFT manufacturing technique that provides for control over both the periodicity of grain boundaries and the location of TFTs in order to provide for uniformity in TFT microstructure.

SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a TFT manufacturing technique that provides for control over both the periodicity of grain boundaries and the location of TFTs in order to provide for uniformity in TFT microstructure.

[0013] Another object of the present invention is to provide a device having uniformity in TFT microstructure.

[0014] In order to meet these and other objects of the present invention which will become apparent with reference to further disclosure set forth below, the present invention provides methods of making a polycrystalline silicon thin-film transistor having a uniform microstructure. One exemplary method requires receiving a polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction, and placing at least portions of one or more thin-film transistors on the received film such that they are tilted relative to the periodic structure of said thin film. The polycrystalline silicon thin film may be formed by a sequential lateral solidification process, e.g., a two shot sequential lateral solidification process.

[0015] Advantageously, the portions of said one or more thin-film transistors may be active channel regions having a width W. Where the periodic structure of the thin film is λ and m is a variable, the placing step involves placing active channel regions on the received film such that they are tilted at an angle θ relative to said periodic structure of said thin film, where $W \sin(\theta) = m \lambda$. The variable m is selected such that that the number of grain boundaries in any of the one or more thin-film transistors remains relatively controlled, and is preferably approximately equal to an integer.

[0016] The present invention also provides a device including a polycrystalline silicon thin-film transistor having a uniform microstructure. In an exemplary embodiment, the device includes polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction, and at least portions of one or more thin-film transistors, placed on the thin film such that they are tilted relative to said periodic structure of the film.

[0017] The accompanying drawings, which are incorporated and constitute part of this disclosure, illustrate preferred embodiments of the invention and serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Fig. 1 is a functional diagram of a prior art system for performing semiconductor processing including sequential lateral solidification;

[0019] Figs. 2a-b are illustrative diagrams showing exemplary processed silicon samples using the prior art system of Fig. 1;

[0020] Figs. 2c-d are illustrative diagrams showing the prior art placement of active channel regions of TFTs on the exemplary processed silicon samples shown in Fig. 2a;

[0021] Figs 3a-b. are illustrative diagrams showing the placement of active channel region of TFTs on the exemplary processed silicon samples shown in Fig. 2a in accordance with the present invention;

[0022] Figs 4a-b. are illustrative diagrams showing the placement of active channel region of TFTs on the exemplary processed silicon samples shown in Fig. 2a in accordance with the present invention; and

[0023] Figs 5a-b. are illustrative diagrams showing the placement of active channel region of TFTs on the exemplary processed silicon samples shown in Fig. 2a in accordance with the present invention.

[0024] Throughout the Figs., the same reference numerals and characters, unless otherwise stated, are used to denote like features, elements, components or portions of the illustrated embodiments. Moreover, while the present invention will now be described in detail with reference to the Figs., it is done so in connection with the illustrative embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Referring again to Figs. 2a-b, exemplary processed silicon thin films using the prior art SLS system of Fig. 1 are shown. In particular, Fig. 2a illustrates a sample processed by irradiating a region with a single excimer laser pulse, micro-translating the sample, and irradiating the region with a second excimer laser pulse. While the following exemplary description of the invention will be with respect to this so-called "2-shot" material as an example, those skilled in the art will appreciate that the present invention is more broadly applicable to silicon thin films that have been processed with n-shot and 2n-shot SLS techniques.

[0026] In accordance with the present invention, active channel regions of TFTs are deliberately tilted relative to the periodic microstructure of the processed thin film. Such tilting may be accomplished by tilting the placement of the channel region itself on the processed thin film, or alternatively, by fabricating a thin film during SLS processing which includes a tilted periodic grain structure. A combination of both alternatives may also be employed.

[0027] The precise methodology for placing TFTs on the processed thin film is not important to the present invention, and hence any known technique may be employed,. One exemplary technique is disclosed in U.S. Patent No. 5,766,989 to Maegawa et al., the contents of which are incorporated by reference herein.

[0028] When the active channel regions of TFTs are deliberately tilted relative to the periodic microstructure of the processed thin film., the spread in the number of perpendicular or long grain boundaries becomes less, leading to an increased device-to-device uniformity. In accordance with the present invention, the tilting angle (θ) should, however, not be too large, as not to increase the influence of the parallel, or short, grain boundaries. The ideal value of θ can be derived from equation (1), in which W is the width of the channel region, λ is the spacing between the perpendicular grain boundaries, and m is preferably close to an integer in value:

$$W * \sin(\theta) = m * \lambda, \qquad (1)$$

[0029] In order to measure performance N of the TFT, equation (2) may be employed, where L is the length of the channel region, and n is a determined ratio:

$$L \cos(\theta) = n * \lambda, \qquad (2)$$

[0030] In equation (2), a lower value of the ration n implies increased performance. L is often defined by the design rule of the process and is equal for all TFTs, and typically ranges from 3 to 6 µm. W, however, can be adjusted to match the requirements on the TFT properties, and typically ranges from 10 to 100s µm. The spacing λ between the perpendicular brain boundaries typically ranges from 2 to 10 µm , but smaller and larger values are possible.

[0031] Referring next to Figs. 3a-b, a first example of the present invention will be described. In this example, the ratio n =1, m =1, and θ = 10 degrees. As shown in Figs. 3a-b, all devices contain one perpendicular grain boundary, regardless of any translation of the TFT device, e.g., from the position shown in Fig 3a to that shown in Fig. 3b.

[0032] Referring next to Figs. 4a-b, a second example of the present invention will be described. In this example, the ratio n = 0.5, m = 1, and θ = 10 degrees. As shown in Figs. 4a-b, the channel region contains two portions, a first 410 in which one perpendicular grain boundary is present, and a second 420 in which no perpendicular grain boundary is present.

[0033] In latter portion 420, the device exhibits behavior as that of a TFT in fully directionally solidified material in which carriers are not hampered by grain boundaries. As shown in Figs. 4a-b, the relative contribution of each of these two parts is again invariable to any translation of the device, e.g., from the position shown in Fig 4a to that shown in Fig. 4b.

[0034] While the examples shown in Figs, 3-4 are considered to be the ideal scenarios, where m is an integer, small deviations from use of an integer value may be used in accordance with the present invention. However, the deviation from an integer value must be selected such that the number of grain boundaries in any given TFT remains relatively controlled.

[0035] Referring next to Figs. 5a-b, further examples of the present invention will be described. In Fig. 5a, the ratio n $= 2.1$, m $= 1$, and $\theta = 10$ degrees; in Fig. 5b, the ratio n $= 2.1$, m $= 0.5$, and $\theta = 5$ degrees. As shown in Figs. 5a-b, for the ideal value of θ, the number of grain boundaries is again invariable to any translation of the device. However, when θ deviates from this value, translations increasingly change the number of grain boundaries. When n equals, or is very close to, an integer the number of grain boundaries is essentially invariant for changes in θ. Of course it should exceed a certain value to assure that the fraction of perpendicular grain that is in the drain region is also invariant to translations.

[0036] The foregoing merely illustrates the principles of the invention. Various modifications and alterations to the described embodiments will be apparent to those skilled in the art in view of the teachings herein. It will thus be appreciated that those skilled in the art will be able to devise numerous systems and methods which, although not explicitly shown or described herein, embody the principles of the invention and are thus within the spirit and scope of the invention.

CLAIMS

1. A method of making a polycrystalline device including two or more thin-film transistors of substantially uniform microstructure, comprising the steps of:

(a) receiving a polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction; and

(b) placing at least portions of two or more thin-film transistors on said received film tilted at an angle relative to said periodic structure of said thin film, such that that the number of long grain boundaries in any of said portions remains substantially uniform.

2. The method of claim 1, wherein said receiving step comprises the step of receiving a polycrystalline silicon thin film formed by a sequential lateral solidification process.

3. The method of claim 1, wherein said portions of said two or more thin-film transistors comprise active channel regions having a width W.

4. The method of claim 3, wherein said periodic structure of said thin film is λ, m is a variable, and said placing step comprises the step of placing said active channel regions on said received film such that said active channel regions are tilted at an angle θ relative to said periodic structure of said thin film, where $W \sin(\theta) = m \lambda$.

5. The method of claim 4, wherein m substantially equal to an integer.

6. The method of claim 4, wherein m is equal to an integer.

7. The method of claim 4, wherein m is equal to the integer 1.

8. A method of making a device including thin-film transistors, comprising the steps of:

(a) receiving a polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction in an amount λ; and

(b) placing at least portions of one or more thin-film transistors having a width W on said received film tilted at an angle θ relative to said periodic structure λ of said thin film, such that $W \sin(\theta) = m \lambda$, where m is substantially equal to an integer.

9. The method of claim 8, wherein said receiving step comprises the step of receiving a polycrystalline silicon thin film formed by a sequential lateral solidification process.

10. The method of claim 8, wherein said portions of said one or more thin-film transistors comprise active channel regions having a width W.

11. The method of claim 10, wherein m is equal to an integer.

12. The method of claim 10, wherein m is equal to the integer 1.

13. A device including two or more polycrystalline silicon thin-film transistors of substantially uniform microstructure, comprising:

(a) a polycrystalline silicon thin film having a grain structure which is periodic in at least a first direction; and

(b) at least two or more thin-film transistor portions placed on said received film, each tilted at an angle relative to said periodic structure of said thin film, such that that the number of long grain boundaries in any of said portions remains substantially uniform.

14. The device of claim 13, wherein said polycrystalline silicon thin film comprises thin film formed by a sequential lateral solidification process.

15. The device of claim 13, wherein said portions of said two or more thin-film transistors comprise active channel regions having a width W.

16. The device of claim 13, wherein said periodic structure of said thin film is λ, m is a variable, and said active channel regions are tilted at an angle θ relative to said periodic structure of said thin film, where $W \sin(\theta) = m \lambda$.

17. The device of claim 16, wherein m is substantially equal to an integer.

18. The device of claim 16, wherein m is equal to an integer.

19. The device of claim 16, wherein m is equal to the integer 1.

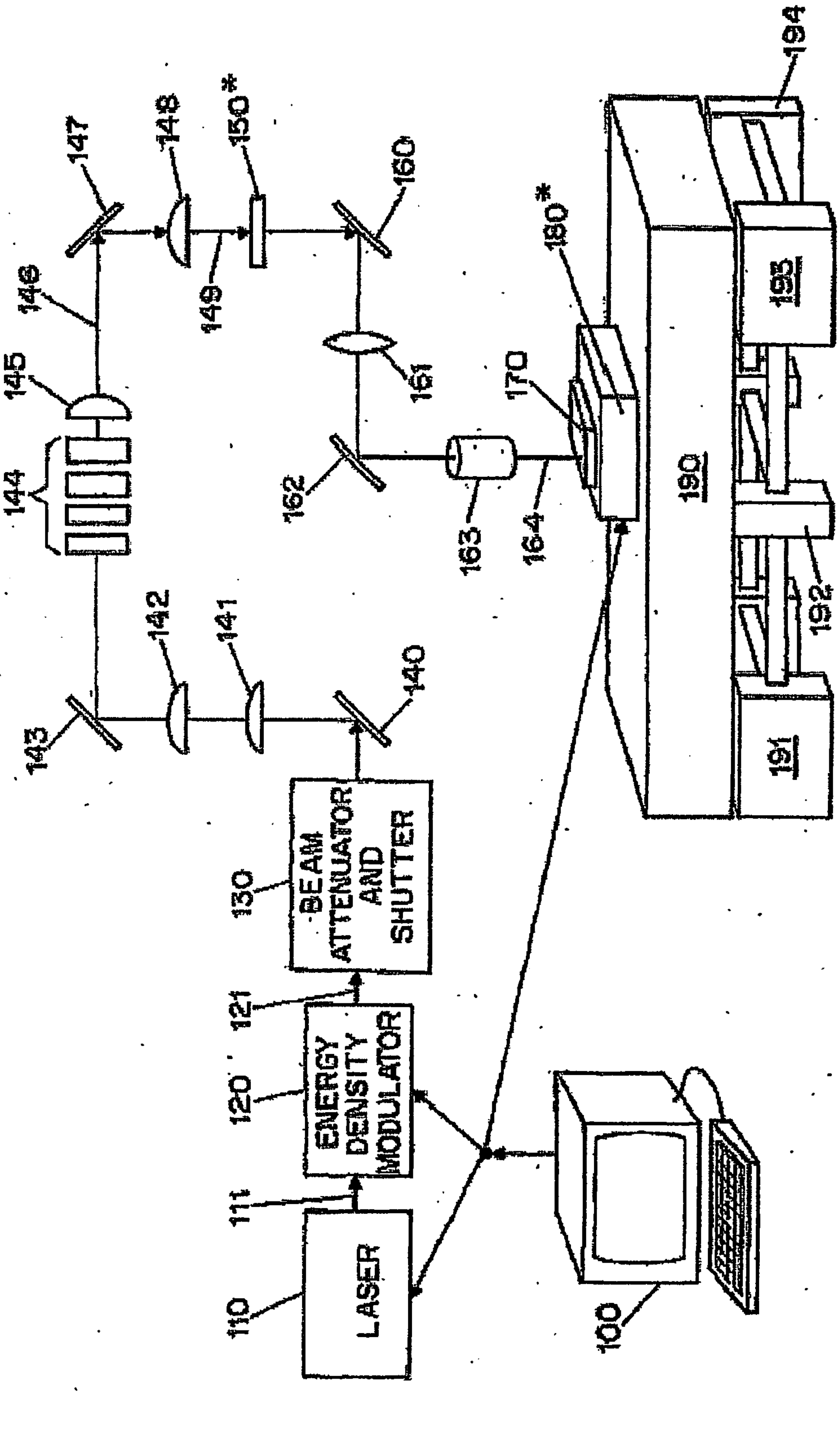


FIG. 1 (Prior Art)

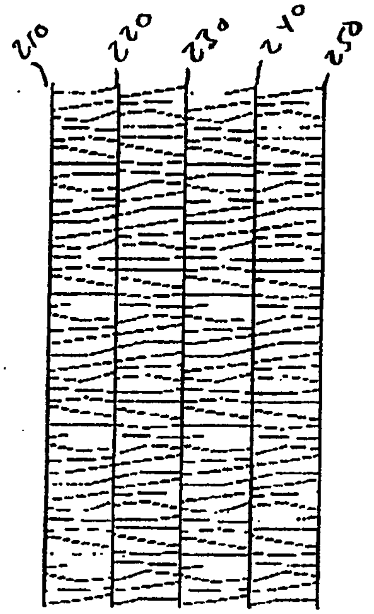


Figure 2a

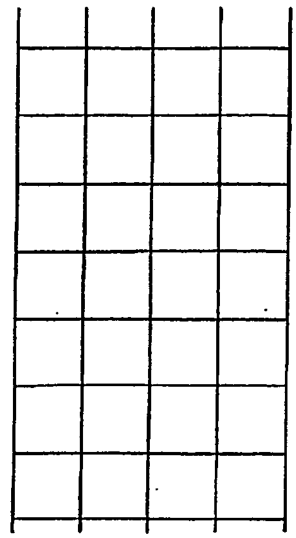


Figure 2b

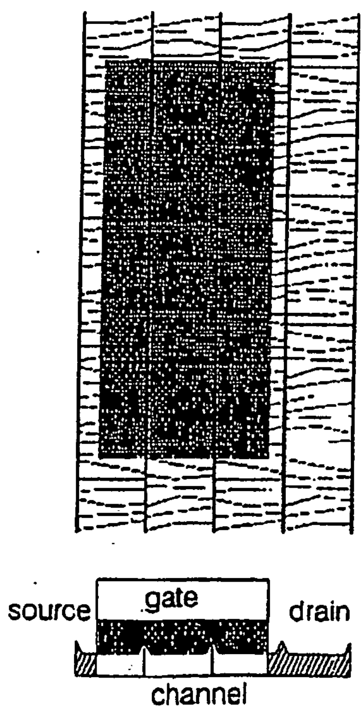


Figure 2c

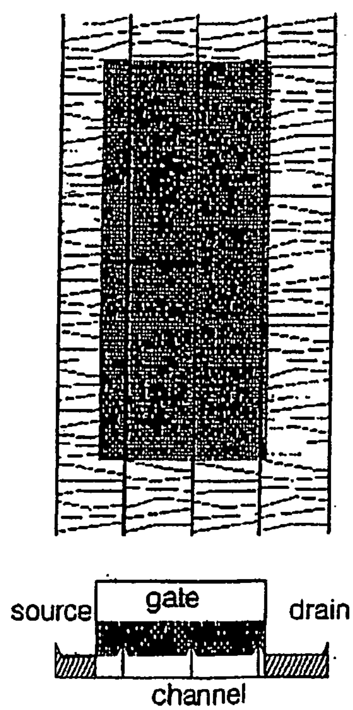


Figure 2d

Fig 3a

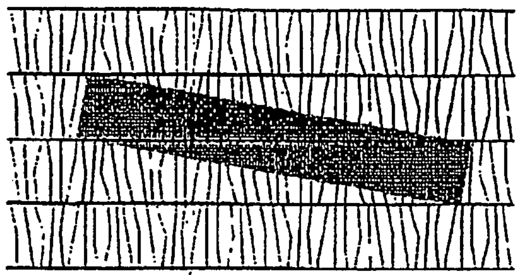


Fig 3b

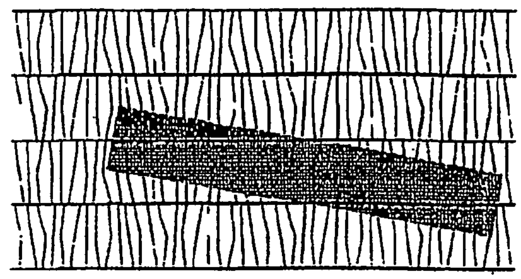


figure 3. n =1 and m = 1, θ = 10°

Fig 4a

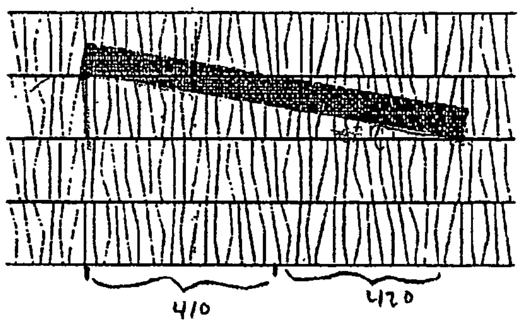


Fig 4b

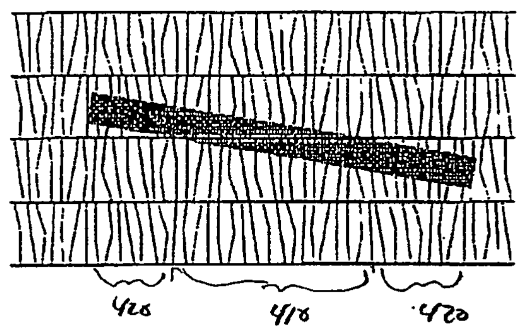


figure 4. n = 0.5, m = 1, θ = 10°

Fig 5a

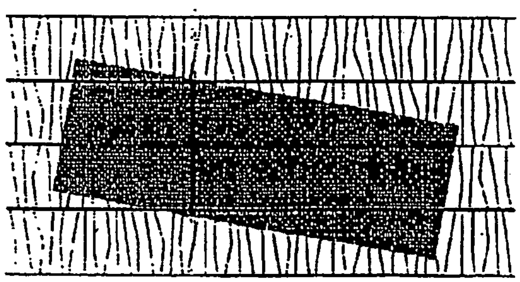


Fig 5b

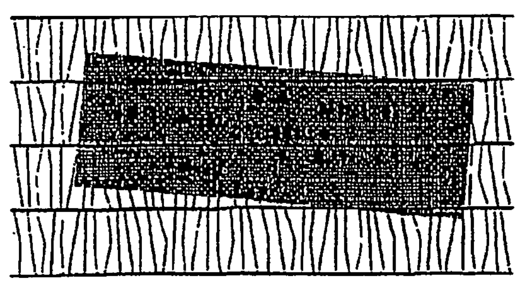


figure 5. left: n = 2.1, m = 1, θ = 10°, right: n = 2.1, m ~ 0.5, θ = 5°

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/27246

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : C30B 13/00
US CL : 117/43
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 117/37, 44, 45, 46, 54, 56, 73, 74, 904, 923; 438/149, 166, 479, 481, 486, 487, 488, 490, 779; 257/45, 75

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 6,322,625 B2 (IM) 27 November 2001 (27.11.2001), Figs. 9 and 10 plus description.	1-19
A	US 4,977,104 A (SAWADA et al) 11 December 1990 (11.12.1990), Fig. 8.	1-19
A	US 6,162,711 A (MA et al) 19 December 2000 (19.12.2000), col. 5, lines 39-47.	1-19
A	US 2001/0001745 A1 (IM et al.) 24 May 2001 (24.5.2001), Figs. 9 and 10, and descriptions.	1-19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 November 2002 (13.11.2002)	11 DEC 2002

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Benjamin Utech
Facsimile No. (703)305-3230	Telephone No. (703) 308-0661

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 October 2003 (16.10.2003)

PCT

(10) International Publication Number
WO 03/084688 A2

(51) International Patent Classification[7]: B21C

(21) International Application Number: PCT/US03/09861

(22) International Filing Date: 1 April 2003 (01.04.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/369,186 1 April 2002 (01.04.2002) US

(71) Applicant *(for all designated States except US)*: **THE TRUSTEES OF COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK** [US/US]; 116th Street and Broadway, New York, NY 10027 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **IM, James, S.** [US/US]; 520 West 114th Street, Apt. 74, New York, NY 10027 (US). **CHOI, Jae, Beom** [KR/US]; 145 East Central Blvd., 2nd Floor, Palisades Park, NJ 07650 (US).

(74) Agents: **TANG, Henry** et al.; Baker & Botts, LLP, 30 Rockefeller Plaza, New York, NY 10112-4498 (US).

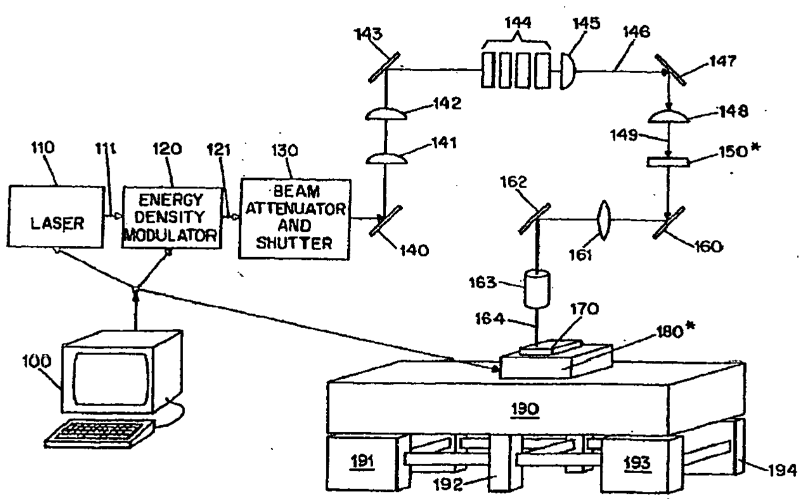
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND SYSTEM FOR PROVIDING A THIN FILM WITH A CONTROLLED CRYSTAL ORIENTATION USING PULSED LASER INDUCED MELTING AND NUCLEATION-INITIATED CRYSTALLIZATION



(57) Abstract: Method and system for generating a metal thin film with a uniform crystalline orientation and a controlled crystalline microstructure are provided. For example, a metal layer is irradiated with a pulsed laser to completely melt the film throughout its entire thickness. The metal layer can then resolidify to form grains with a substantially uniform orientation. The resolidified metal layer can be irradiated with a sequential lateral solidification technique to modify the crystalline microstructure (*e.g.*, create larger grains, single-crystal regions, grain boundary controlled microstructures, etc.) The metal layer can be irradiated by patterning a beam using a mask which includes a first region capable of attenuating the pulsed laser and a second region allowing complete irradiation of sections of the thin film being impinged by the masked laser beam. An inverse dot-patterned mask can be used, the microstructure that may have substantially the same as the geometric pattern as that of the dots of the mask.

WO 03/084688 A2

Method and System for Providing a Thin Film with a Controlled Crystal Orientation Using Pulsed Laser Induced Melting and Nucleation-Initiated Crystallization

Cross-Reference to Related Application(s)

This application claims priority from United States Application Serial No. 60/369,186 filed April 1, 2002, the entire disclosure of which is incorporated herein by reference.

Notice of Government Rights

The U.S. Government may have certain rights in this invention pursuant to the terms of the Defense Advanced Research Project Agency award number N66001-98-1-8913.

Field of the Invention

The present invention relates to a system and process for producing a metal thin film having a uniform crystal orientation and controlled microstructure. In particular, the system and process of the present invention utilize a pulsed laser beam in conjunction with sequential lateral solidification ("SLS") techniques to produce, e.g., an aluminum thin film with, preferably, a (111) crystal orientation.

Background of the Invention

An inherent problem in the production of metallic thin films is minimizing the electro-migration that occurs in the metal interconnects. The electro-migration results in the transport of metal material of an interconnect line, and is caused when free electrons dislodge the atoms of the conductive material upon the current density increase that occurs due to smaller cross-sectional dimensions of the interconnect lines. The electro-migration occurs due to the transfer of momentum from the electrons flowing in a metal conductor when the conductor fails, because of a void or break in the conductor. This phenomenon is generally known as an "electron wind." The failure occurs most often along the grains of the conductive material since the atoms are not as firmly bound along the grains, and the grains provide efficient paths for the electron transport. These grains may extend in a direction which is parallel to the direction of the interconnect lines, i.e., along the direction of the current flow, which is considered to be particularly undesirable (i.e., such grain direction results in

an increased electro-migration). If vacancies or voids are formed in the conductive material, the void that is formed reduces the cross-sectional area in a region of the interconnect through which the current may flow, effectively raising the current density of that region of the interconnect even further. Therefore, the void may become so large that an open circuit or a break in the interconnect line results. Alternatively, the atoms of the conducting material that are dislodged may accumulate in a region of the interconnect so as to form a protrusion. If the protrusion becomes large enough, a contact with an adjacent interconnect may occur, thereby causing an undesired connection between the adjacent interconnect lines.

As the features of integrated semiconductor circuit chips are reduced, the cross-section of the metal interconnect lines on the integrated circuit chips are also reduced. This decrease in the cross-sectional dimensions increases the current density in the interconnect lines, which creates increased electro-migration in the metal interconnects. Moreover, the electro-migration would likely increase with a presence of a random orientation of the microstructure of the thin film. Since increasing the grain size to be larger than the metallization line width and preparing semiconductor films with a uniform orientation would reduce the propensity for electro-migration failure, there is a need for a system and method to control crystallization, and produce thin films with the substantially uniform orientation of the microstructure of the thin film.

Control over the thin film microstructure may be obtained through the use of sequential lateral solidification ("SLS") techniques. For example, U.S. Patent No. 6,322,625 (the "'625 application"), U.S. Patent Application Serial Nos. 60/239,194 (the "'194 application"), 09/390,535 (the "'535 application"), 09/390,537 (the "'537 application"), 60/253,256 (the "'256 application"), 09/526,585 (the "'585 application") and International Patent Application Nos. PCT/US01/31391 and PCT/US01/12799, the entire disclosures of which are hereby incorporated herein by reference, describe advantageous apparatus and methods for growing large grained polycrystalline or single crystal structures using energy-controllable laser pulses and small-scale translation of a sample to implement the SLS techniques. As described in these patent documents, at least portions of the semiconductor film on a substrate are irradiated with a suitable radiation pulse to completely or partially melt such portions of the film throughout their thickness. In this manner, when the molten semiconductor material solidifies, a crystalline structure grows into the solidifying portions from selected

areas of the semiconductor film which did not undergo a complete melting. Thereafter, the beam pulses irradiate slightly offset from the crystallized areas so that the grain structure extends into the molten areas from the crystallized areas. With the SLS techniques, and the systems described therein, crystallization may be controlled to modify the microstructure of the thin film (e.g., by creating larger grains, single-crystal regions, grain-boundary-location-controlled microstructures), and produce grains with a particular orientation.

Summary of the Invention

One of the objects of the present invention is to produce at least one section of a metal layer having a uniform crystal orientation and a controlled microstructure. In particular, the present invention may be used to produce an aluminum metal layer having a controlled crystal orientation of microstructures provided therein. For example, a pulsed laser beam may be utilized in conjunction with a sequential lateral solidification ("SLS") technique to produce a (111) crystal orientation of an aluminum thin film with.

In one exemplary embodiment of the present invention, a method and system are provided for processing a sample having a metal layer to generate a polycrystalline film with a controlled crystal orientation. In particular, at least one portion of the metal layer can be irradiated with a pulsed laser, so that the metal layer is completely melted throughout its entire thickness. Such portion of the metal layer is then resolidified via the crystalline growth, so that the grains of the metal layer have a substantially uniform orientation therein. In another embodiment of the present invention, the metal layer may be deposited on a substrate, which may be done by sputtering, evaporation or any conventional method. In yet another exemplary embodiment, the metal layer may be composed of aluminum or an aluminum alloy (e.g., an aluminum-copper alloy, an aluminum-silicon alloy, an aluminum-copper-silicon alloy etc.) In a further embodiment of the present invention the substantially uniform orientation may be a (111) orientation

In still another exemplary embodiment of the present invention, the metal layer can be irradiated without patterning (i.e., flood irradiate) to obtain grains with a uniform orientation. The metal layer is then irradiated using the SLS technique, as described in the above-identified patent applications. Certain masks and mask patterns can be used for the SLS techniques to generate various shapes of grain

boundaries for modifying the microstructure. This is done by, e.g., creating larger grains, single-crystal regions, grain-boundary-location-controlled microstructures, etc.

In a still further embodiment of the present invention, a mask used during the sequential solidification technique includes a first region capable of attenuating the pulsed laser and a second region which allows substantially the entire intensity of the corresponding portion of the pulsed laser to pass therethrough. The mask may be an inverse dot-patterned mask. The entire thin film can be completely melted throughout its entire thickness and the attenuation may be such that the region of the metal layer corresponding to the first region reaches a lower temperature than the melting temperature of the metal layer and lower than that the temperature of the section of the metal layer irradiated by the beam that is shaped by the second region. In yet another embodiment of the present invention, the dot patterns of the mask can be spaced closer than the super lateral growth distance which is based on the relevant process temperature. The inverse dot-patterned mask can include dots arranged in a geometric pattern such that the microstructure of the metal layer irradiated using such mask crystallizes in substantially the same geometric pattern as the arrangement of the dots of the inverse dot-patterned mask. The dots of the inverse dot-patterned mask may also be arranged to irradiate the metal layer microstructure in a manner to a hexagonal pattern or a square pattern therein.

Brief Description of the Drawings

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description, taken in conjunction with the accompanying drawings, and its scope will be pointed out in the appending claims.

Figure 1 shows a block diagram of a system for performing a preferred embodiment of a lateral solidification process according to an exemplary embodiment of the present invention;

Figure 2 shows an illustration of a section of an exemplary aluminum thin film sample after pulsed laser irradiation to induce complete melting and subsequent solidification of a section of an aluminum sample;

Figure 3 shows an enlarged representation of a portion of the section illustrated in Figure 2;

Figure 4 shows inverse pole symbols representing the nucleated aluminum grains of the sample of Figure 3 illustrating that the nucleated aluminum grains have a (111) orientation;

Figure 5 shows an exemplary embodiment of an inverse dot-patterned mask with the dot patterns arranged in a hexagonal form, which may be used with the exemplary system and process according to the present invention;

Figure 6 shows an exemplary temperature profile of the melted aluminum thin film sample after irradiation of a portion thereof with the inverse dot-patterned mask of Figure 5;

Figure 7 shows an exemplary section of the sample after the Sequential lateral solidification ("SLS") is utilized using the inverse dot-patterned mask of Figure 5;

Figure 8 shows an enlarged illustration of approximately hexagonal portions of the sample shown in Figure 7;

Figure 9 shows inverse pole symbols representing nucleated aluminum grains of the sample of Figures 7 and 8 illustrating that the nucleated aluminum grains have a (111) orientation; and

Figure 10 shows a flow diagram of an exemplary embodiment of a method according to the present invention which can be implemented by the system of Figure 1.

Throughout the Figures, the same reference numerals and characters, unless otherwise stated, are used to denote like features, elements, components or portions of the illustrated embodiments. Moreover, while the present invention will now be described in detail with reference to the Figures, it is done so in connection with the illustrative embodiments.

Detailed Description

In one exemplary embodiment of the present invention, a uniform crystalline orientation of at least one section of a metal thin film may be obtained using the sequential lateral solidification process. Therefore, in order to fully understand the present invention, the sequential lateral solidification process is further described. As disclosed in aforementioned patent applications, the sequential lateral solidification ("SLS") process is a technique for producing large grained thin films through small-scale unidirectional translation of a sample between sequential pulses emitted by an excimer laser. As each pulse is absorbed by the sample, a small area of the sample is

caused to melt completely, and then resolidify laterally into a crystal region produced by the preceding pulses of a pulse set. It should be understood that various systems according to the present invention may be utilized to generate, nucleate, solidify and crystallize one or more areas on the thin film (e.g., composed of aluminum) which have uniform material therein, such that at least an active region of a thin-film transistor ("TFT") may be placed in such areas. The exemplary embodiments of the systems and processes of the present invention to generate such areas, as well as those of the resulting crystallized metal thin films, shall be described in further detail below. However, it should be understood that the present invention is in no way limited to the exemplary embodiments of the systems, processes and semiconductor thin films described herein.

Figure 1 shows a system that includes excimer laser 110, energy density modulator 120 to rapidly change the energy density of laser beam 111, beam attenuator and shutter 130, optics 140, 141, 142 and 143, beam homogenizer 144, lens system 145, 146, 148, a mask or masking system 150, lens system 161, 162, 163, incident laser pulse 164, thin metal film sample 170, sample translation stage 180, granite block 190, support system 191, 192, 193, 194, 195, 196, and managing computer 100. As described in further detail in the '535 application, a non-processed thin film sample 170 may be processed into a single or polycrystalline metal thin film by generating a plurality of excimer laser pulses of a predetermined fluence, controllably modulating the fluence of the excimer laser pulses, homogenizing the modulated laser pulses in a predetermined plane, masking portions of the homogenized modulated laser pulses into patterned beamlets, irradiating an amorphous silicon thin film sample with the patterned beamlets to effect melting of portions thereof corresponding to the beamlets, and controllably translating the sample with respect to the patterned beamlets and with respect to the controlled modulation to thereby process the amorphous thin film sample into a single or polycrystalline thin film by sequential translation of the sample relative to the patterned beamlets and irradiation of the sample by patterned beamlets of varying fluence at corresponding sequential locations thereon. The laser system may include a laser source, optics, mask, and projection system, which may be substantially the same as or similar to the equipment used for other SLS systems and processes.

In an exemplary embodiment of the present invention, the method and system may be used to generate metal thin films (e.g., aluminum film) with a uniform

crystalline orientation. The thin film may be composed of aluminum alloys such as, e.g., Al-Cu, Al-Si, Al-Cu-Si, etc. In such exemplary embodiment, the concentration of the impurities may preferably be less than 20%.

The aluminum thin film sample may be deposited on a substrate by various methods, such as sputtering, evaporation, etc. In one exemplary embodiment of the present invention, it is possible to use the polycrystalline aluminum films without the need to place it on a substrate. In one exemplary embodiment, at least one portion of the aluminum thin film layer is irradiated with a pulsed laser (e.g., an excimer laser) without patterning of the beam pulse (i.e. flood irradiation). The entire portion of the metal layer is completely melted, preferably throughout its entire thickness. The completely melted liquefied section of the aluminum thin film solidifies via nucleation and crystalline growth thus resulting in an aluminum thin film as shown in Figure 2. Figure 3 shows a representation of an enlarged portion of the resolidified section illustrated in Figure 2 indicating that the complete melting and solidification of the section(s) of the aluminum thin film results in grain boundaries 200 and grain shapes 202 that are relatively random.

According to another exemplary embodiment of the present invention, the resolidified (and possibly nucleated) grains of the aluminum layer provided as a substrate can have a substantially uniform orientation after irradiation and solidification. The nucleated aluminum grains likely have a uniform (111) orientation. Such exemplary orientation of the aluminum grains may preferably occur through the heterogeneous nucleation at an interface between liquid aluminum and the substrate. For example, the (111) planes of the aluminum grains likely have the lowest surface energy, which reduces the activation energy for the heterogeneous nucleation. Thus, the (111) orientation of the aluminum grains is thermodynamically preferred according to the present invention. Figure 4 shows inverse pole symbols representing an exemplary portion of the resolidified section of the aluminum thin film of Figure 2 illustrating that the crystallized aluminum grains have various orientations, and in particular, a (111) orientation. In an exemplary embodiment of the system and process according to the present invention, it is possible to obtain the (111)-oriented polycrystalline aluminum films by positioning the sample 170 in a predetermined manner and subjecting the thin film to the SLS processing. This can be done after the thin film is subject to flood irradiation.

In another exemplary embodiment of the present invention, it is possible to initially irradiate a portion of the aluminum thin film sample without patterning (i.e., by flood irradiating), so as to allow the irradiated portions of thin film to solidify, so as to obtain grains having a (111) orientation, and then irradiate such previously-irradiated portion of the metal layer using the SLS process, as described in the above-identified patent applications and patents. Depending on the masks and their mask patterns (the examples of which are described and shown in the above-identified applications and patents), it is possible to generate various shapes of grain boundaries so as to modify the metal microstructure and the orientation of the grains thereof (e.g., by creating larger grains, single-crystal regions, grain-boundary-location-controlled microstructures, etc.).

The mask 150 may include a first region capable of attenuating the pulsed laser and a second region that allows the associated portions of complete pulsed laser to irradiate therethrough. For example, an inverse dot-patterned mask may be used in which the dots are arranged in a geometric pattern such that the microstructure of the metal layer crystallizes substantially corresponds to the geometric shape of the arrangement of the dots of the mask pattern. In a further embodiment of the present invention, similarly to the conventional SLS techniques which utilize dot-patterned masks, the dot patterns on such mask should be spaced closer to one another than the super lateral growth distance corresponding to the relevant process temperature. As described in the applications and patents identified herein above, the dot regions of the inverse dot patterned mask may be arranged to form a metal layer with a hexagonal microstructure as shown in Figure 5. In particular, the exemplary mask of Figure 5 includes a first region 500 that attenuates the beam intensity and a second region 502 that allows the beam to pass therethrough to reach and irradiate the aluminum thin film. It is preferable for the energy density of the beam to be large enough to completely melt the intended sections of the aluminum thin film, including the regions masked by the dots 500. Since the dots 500 are opaque, and the beam is significantly attenuated in those regions, the aluminum thin film area positioned to be irradiated by the dot regions (although completely melted) would likely not reach as high of a temperature as that of the areas outside the dot regions (which are also completely melted) as is shown in Figure 6. In particular, the temperature 501 in the attenuated region o f the aluminum thin film should be lower than the melting temperature of the film so that at least some of (111) nucleated grains that are formed

remain as solids (e.g., via a previous irradiation such as the flood irradiation) to seed the molten metal around those solid regions into the (111) oriented grains.

As the film cools, the section of the aluminum thin film irradiated by the section of the laser beam masked the dot regions nucleates, thus, providing the (111) oriented seeds that grow laterally into the non-masked areas in accordance with the principles of SLS techniques described in the above-identified U.S. and International patent applications and patents. In particular the dot-patterned SLS techniques described therein. As described in these patent documents, the microstructure that is obtained depends on the geometry of the dot regions of the mask 150. Therefore, as shown in Figures 7 and 8, the use of the exemplary inverse dot-patterned mask of Figure 5 to mask the laser beam and irradiate the aluminum thin film results in crystallized aluminum film with a hexagonal microstructure. Figure 8 shows an enlarged representation of a portion of the section provided in Figure 7 further illustrating the locations and shapes of the grain boundaries 800, 802, respectively. Figure 9 shows inverse pole symbols representing the portion of the section provided in Figure 8 that illustrate that the crystallized aluminum grains have substantially a (111) orientation. In a further exemplary embodiment of the present invention, the dot regions of the inverse dot patterned mask may be arranged so as to generate the sections of the metal thin film with square microstructure therein.

Referring to Figure 10, exemplary steps executed by computer 100 of Figure 1 to control the irradiation and grain orientation of the metal thin film is described. The various electronics of the system shown in Figure 1 are initialized by the computer to initiate the process in step 1000. A thin metal (aluminum) film sample 170 is then loaded onto the sample translation stage in step 1005. It should be noted that such loading may be either manual or robotically implemented under the control of the computer 100.

Next, the sample translation stage 180 is moved into an initial position in step 1010, which may include an alignment with respect to reference features on the sample 170. The various optical components of the system are focused in step 1015 if necessary. The laser is then stabilized in step 1020 to a desired energy level and repetition rate, as needed to fully melt the metal thin film sample 170 in accordance with the particular processing to be carried out. If necessary, the attenuation of the laser pulses is finely adjusted (step 1025).

Next, the sample 170 is positioned to point the beam to impinge on the first section of sample in step 1030. The beam 149 is masked with the appropriate mask pattern of the mask 150 (step 1035). It is also possible to not mask the beam prior to its impingement of the sample 170. After the beam 149 is masked to become a masked beam pulse 164, the masked beam pulse 164 irradiates at least one section of the metal (aluminum) thin film sample 170 to produce grains that have a particular (e.g., - 111) orientation in step 1040. Then, in step 1045, it is determined whether all intended areas of the thin metal film sample 170 have been irradiated in a predetermined manner. If not, the sample 170 is then translated in the X and/or Y directions in step 1050 for a distance which is less than the super lateral grown distance of the metal thin film using the SLS and/or non-SLS techniques. After processing all of the desired sections of the metal thin film sample 170, the beam and hardware are shut off in step 1055 and the process is completed in step 1060. If processing of additional samples is desired or steps 1005 – 1050 may be repeated for each such sample.

In addition, it is also possible to obtain the (111) oriented grains using the SLS techniques described above and without the flood irraditions being effectuated on the aluminum thin film prior to such SLS processing. In particulars, the desired sections of the aluminum thin film 170 are irradiated using the one of the patterned masks described above (e.g., the dot-patterned mask, the hexagonal-shaped mask, the rectangular shaped mask, etc.) and the SLS techniques in order to nucleate center areas corresponding to the such shapes (which allow some or all of the irradiation of the beam pulse to pass therethrough). The resolidified desired regions of the aluminum thin film 170 result in the (111) oriented grains, which are also grain boundary controlled grains. Accordingly, it is not necessary to subject the aluminum thin film 170 to flood irradiation prior to it being irradiated using the SLS processing technique.

The foregoing merely illustrates the principles of the invention. Various modifications and alterations to the described embodiments will be apparent to those skilled in the art in view of the teachings herein. For example, while the above embodiment has been described with respect to at least partial lateral solidification and crystallization of the semiconductor thin film, it may apply to other materials processing techniques, such as micro-machining, photo-ablation, and micro-patterning techniques, including those described in the above-identified patent documents. The

various mask patterns and intensity beam patterns described in the above-referenced patent application may also be utilized with the process and system of the present invention. It will thus be appreciated that those skilled in the art will be able to devise numerous systems and methods which, although not explicitly shown or described herein, embody the principles of the invention and are thus within the spirit and scope of the present invention.

Claims

1. A method for processing a sample having a metal thin film provided thereon to generate a polycrystalline film with a substantially uniform orientation, comprising the steps of:

(a) irradiating at least one portion of the metal thin film with a pulsed laser to completely melt the at least one portion throughout its entire thickness; and

(b) allowing the melted metal thin film to re-solidify after the at least one portion is melted, wherein the grains of the at least one resolidified portion of the metal thin film have the substantially uniform orientation.

2. The method according to claim 1, wherein the metal thin film is deposited on a substrate.

3. The method according to claim 2, wherein the metal thin film is deposited on a substrate by at least one of a sputtering procedure, an evaporation procedure and a further thin film deposition procedure.

4. The method according to claim 1, wherein the metal thin film is composed of aluminum.

5. The method according to claim 1, wherein the metal thin film is composed of an aluminum alloy, the aluminum alloy including at least one of an aluminum-copper alloy, an aluminum-silicon alloy and an aluminum-copper-silicon alloy.

6. The method according to claim 1, wherein the substantially uniform orientation is a (111) orientation.

7. The method according to claim 1, further comprising the step of:

(c) irradiating the at least one portion of the metal thin film with the laser pulse based on a sequential lateral solidification technique.

8. The method according to claim 7, wherein the laser pulse irradiating the at least one portion is patterned using a mask to modify a shape of the laser pulse.

9. The method according to claim 8, wherein the mask is comprised of a first region capable of attenuating the pulsed laser and a second region allowing a significant section of the laser beam impacting the second region to pass therethrough.

10. The method according to claim 9, wherein the mask is an inverse dot-patterned mask, and wherein the second region includes opaque array patterns which include at least one of dot-shaped areas, hexagonal-shaped areas and rectangular-shaped areas.

11. The method according to claim 10, wherein each portion of the metal thin film is completely melted throughout its entire thickness, and wherein an attenuation of the laser beam produced by the first region impinges associated section of the thin film to reach a temperature that is lower than a melting temperature of the metal thin film and lower than a temperature as further sections of the thin film corresponding with the areas irradiated by the second region.

12. The method according to claim 11, wherein dot patterns of the mask are spaced closer than a super lateral growth distance corresponding to a resolidification process temperature of the metal thin film.

13. The method according to claim 10, wherein the inverse dot-patterned mask is comprised of dots has a geometric pattern such that upon the irradiation of the metal thin film, a microstructure of the metal thin film solidifies and crystallizes in substantially the same geometric pattern as the pattern of the inverse dot-patterned mask.

14. The method according to claim 13, wherein the dots of the inverse dot-patterned mask are arranged in a pattern such that upon the irradiation of the metal thin film with the masked laser beam, a microstructure of the metal thin film is formed having one of a hexagonal pattern, a rectangular pattern and a square pattern.

15. The method according to claim 7, wherein, in step (a), a width of the at least one irradiated portion is greater than a super-lateral growth width of the metal thin film.

16. The method according to claim 1, wherein step (a) is performed using a sequential lateral solidification technique, and wherein, upon the execution of step (a), in step (b), grain-boundary location controlled grains are formed in the at least one portion of the metal thin film.

17. A system for producing at least one section of a polycrystalline metal film with a substantially uniform orientation, comprising:

a logic arrangement which is operable to:

(a) irradiate at least one portion of the at least one portion of the metal thin film to completely melt the at least one portion of the metal thin film throughout its entire thickness, and

(b) allow the at least one portion of the melted metal thin film to re-solidify after the at least one is melted, wherein the grains of the at least one portion have the substantially uniform orientation upon the re-solidification.

18. The system according to claim 17, wherein the metal thin film is deposited on a substrate.

19. The system according to claim 18, wherein the metal thin film is deposited on a substrate by at least one of a sputtering procedure, an evaporation procedure and a further thin film deposition procedure.

20. The system according to claim 17, wherein the metal thin film is composed of aluminum.

21. The system according to claim 17, wherein the metal thin film is composed of an aluminum alloy, the aluminum alloy including at least one of an aluminum-copper alloy, an aluminum-silicon alloy and an aluminum-copper-silicon alloy.

22. The method according to claim 17, wherein the substantially uniform orientation is a (111) orientation.

23. The system according to claim 17, where the logic arrangement is further operable to irradiate the at least one portion of the thin film sample with a sequential lateral solidification technique.

24. The system according to claim 23, wherein the laser pulse irradiating the at least one portion is patterned using a mask to modify a shape of the laser pulse.

25. The system according to claim 24, wherein the mask is comprised of a first region capable of attenuating the pulsed laser and a second region allowing a significant section of the laser beam impacting the second region to pass therethrough.

26. The system according to claim 25, wherein the mask is an inverse dot-patterned mask, and wherein the second region includes opaque array patterns which include at least one of dot-shaped areas, hexagonal-shaped areas and rectangular-shaped areas.

27. The system according to claim 26, wherein each portion of the metal thin film is completely melted throughout its entire thickness, and wherein an attenuation of the laser beam produced by the first region impinges associated section of the thin film to reach a temperature that is lower than a melting temperature of the metal thin film and lower than a temperature as further sections of the thin film corresponding with the areas irradiated by the second region.

28. The system according to claim 27, wherein dot patterns of the mask are spaced closer than a super lateral growth distance corresponding to a resolidification process temperature of the metal thin film.

29. The system according to claim 28, wherein the inverse dot-patterned mask is comprised of dots has a geometric pattern such that upon the irradiation of the metal thin film, a microstructure of the metal thin film solidifies and

crystallizes in substantially the same geometric pattern as the pattern of the inverse dot-patterned mask.

30. The system according to claim 29, wherein the dots of the inverse dot-patterned mask are arranged in a pattern such that upon the irradiation of the metal thin film with the masked laser beam, a microstructure of the metal thin film is formed having one of a hexagonal pattern, a rectangular pattern and a square pattern.

31. The system according to claim 17, wherein the logic arrangement irradiates the at least one portion of metal using a sequential lateral solidification technique, and wherein, upon the completion of step (b), grain-boundary location controlled grains are formed in the at least one portion of the metal thin film.

32. A polycrystalline metal film, comprising:

at least one portion which is irradiated to be completely melted throughout its entire thickness, wherein the at least one portion is re-solidified after being melted, and wherein the at least one portion include grains which have a substantially uniform orientation upon the re-solidification of the at least one portion.

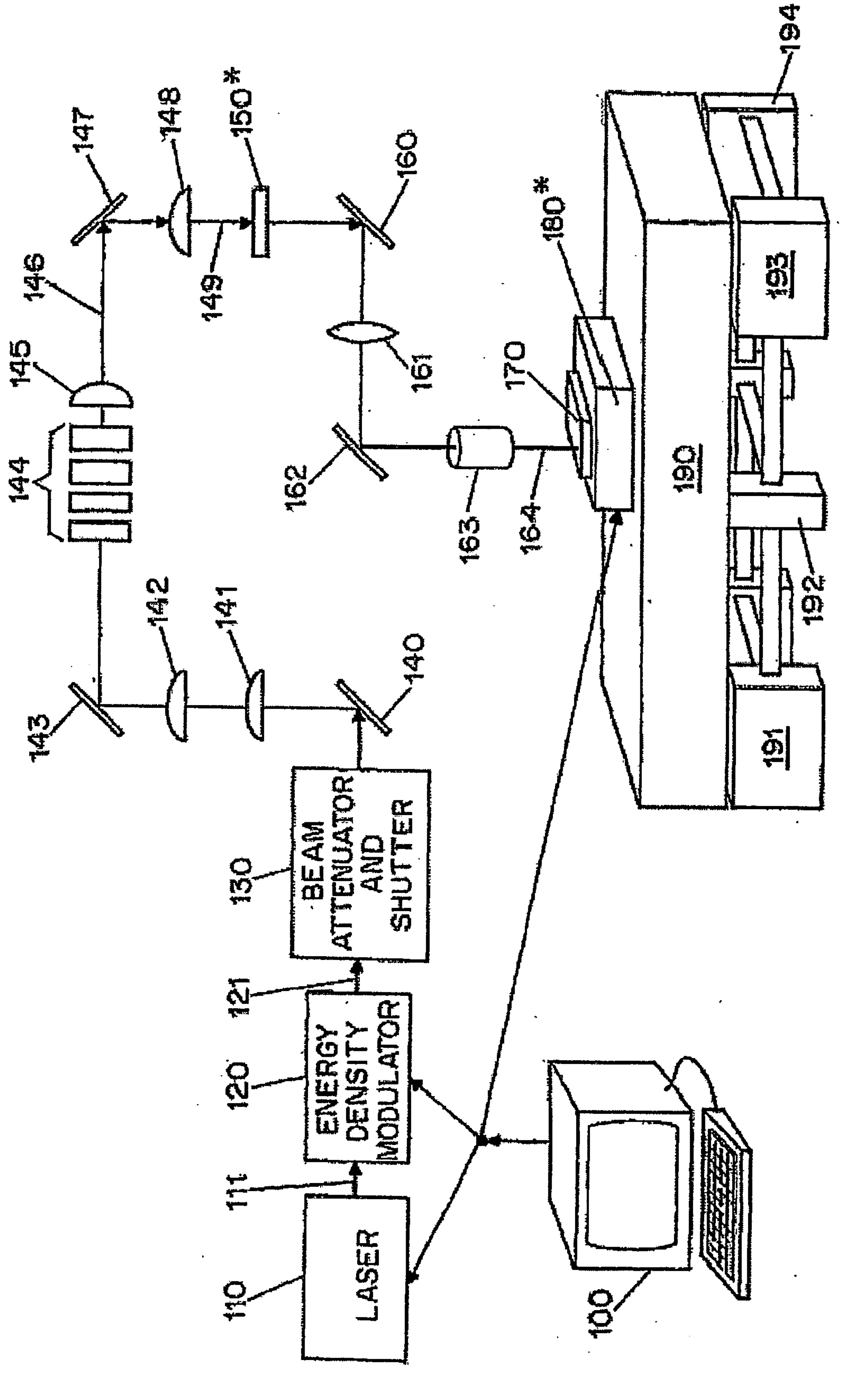

LASER
ENERGY DENSITY MODULATOR
BEAM ATTENUATOR AND SHUTTER
100
110
111
120
121
130
140
141
142
143
144
145
146
147
148
149
150*
160
161
162
163
164
170
180*
190
191
192
193
194

FIGURE 1

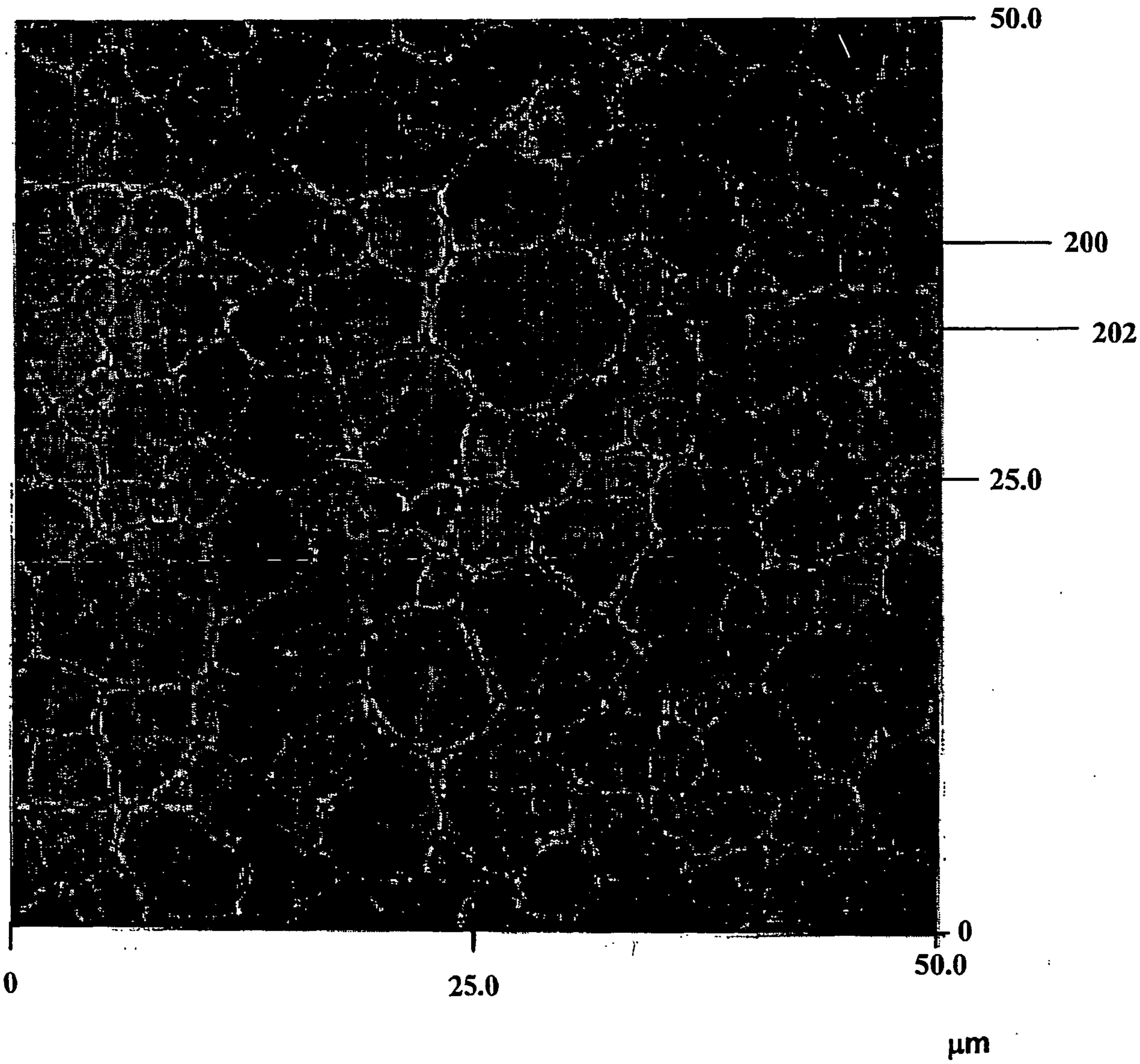


FIGURE 2

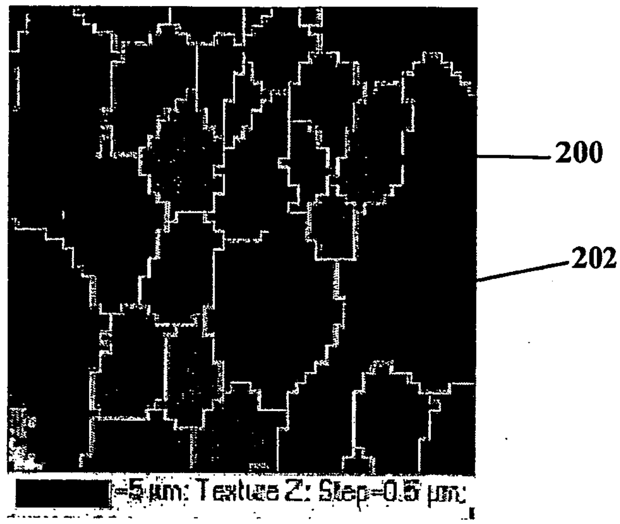


FIGURE 3

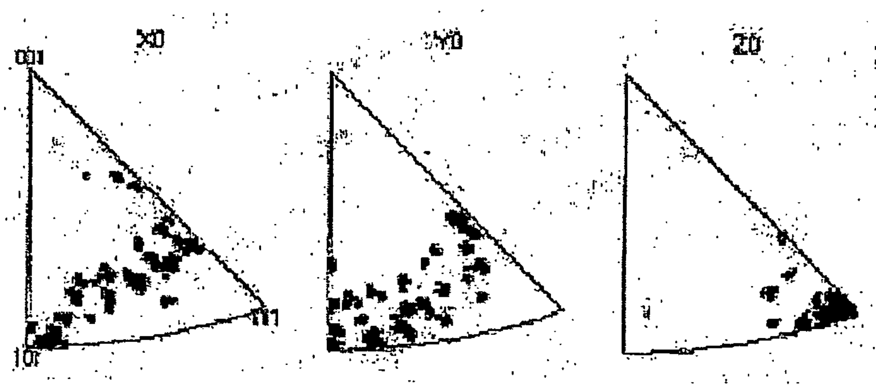


FIGURE 4

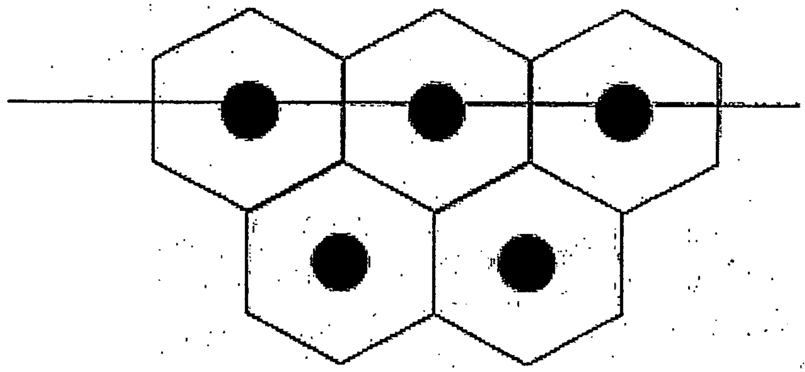


FIGURE 5

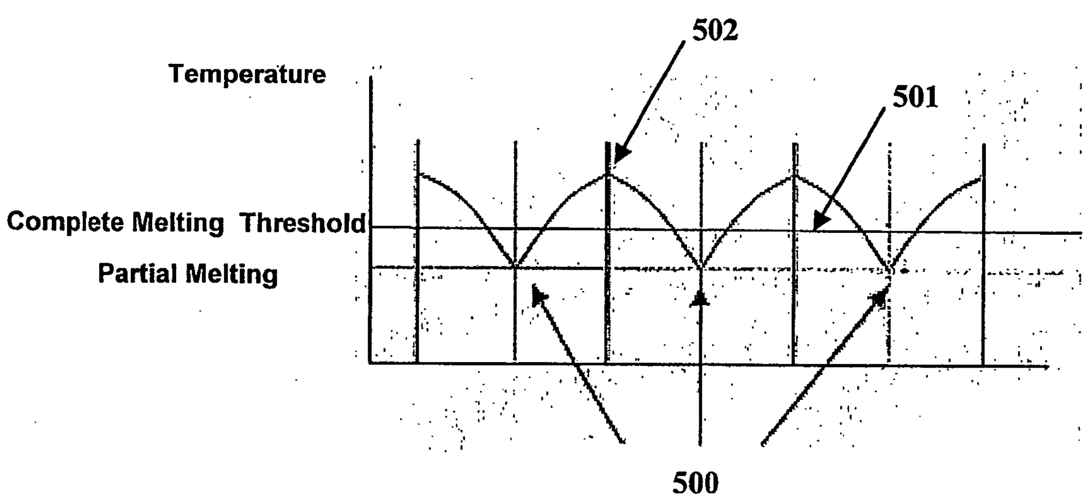


FIGURE 6

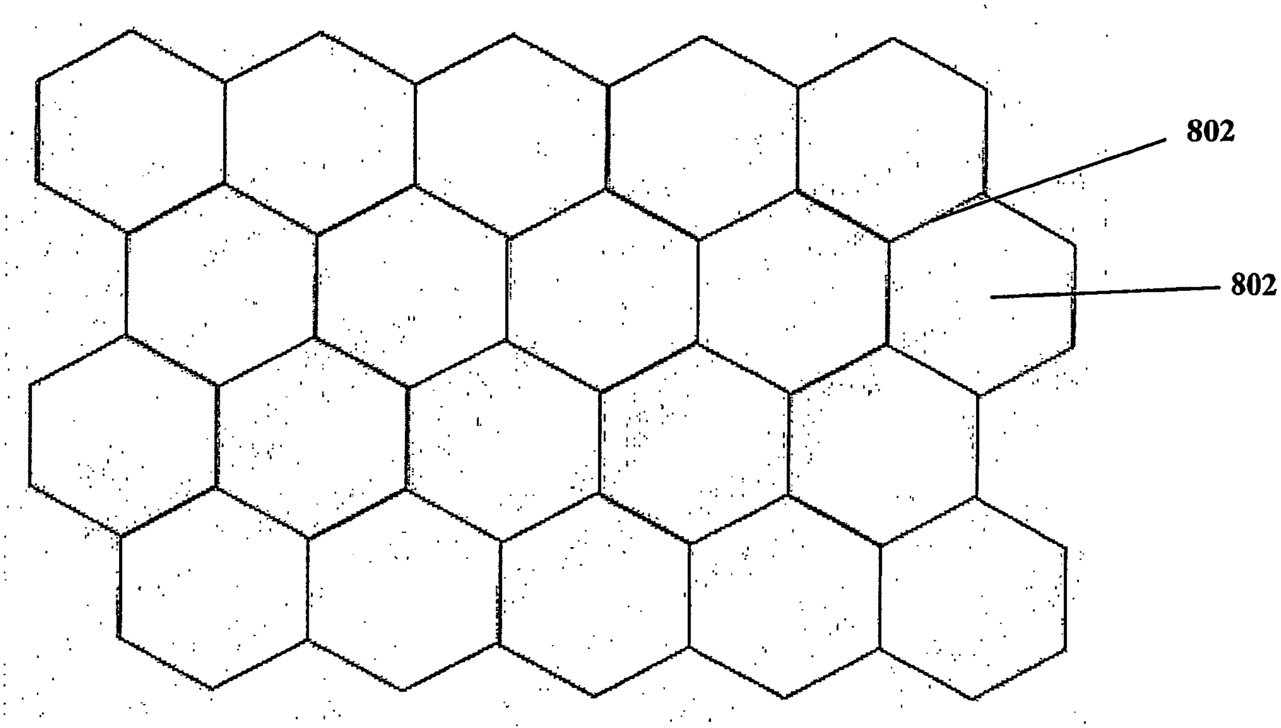


FIGURE 7

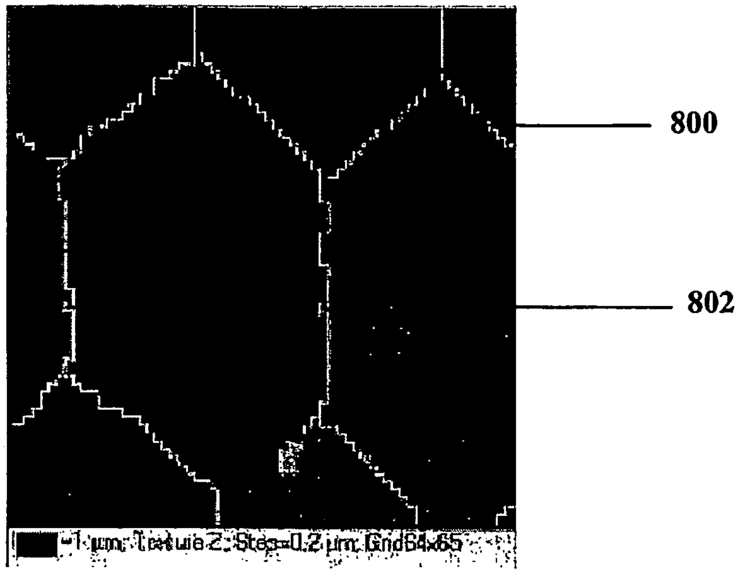


FIGURE 8

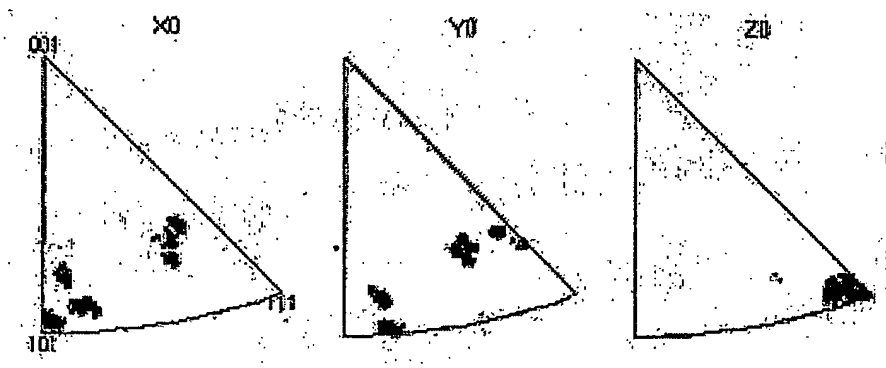


FIGURE 9

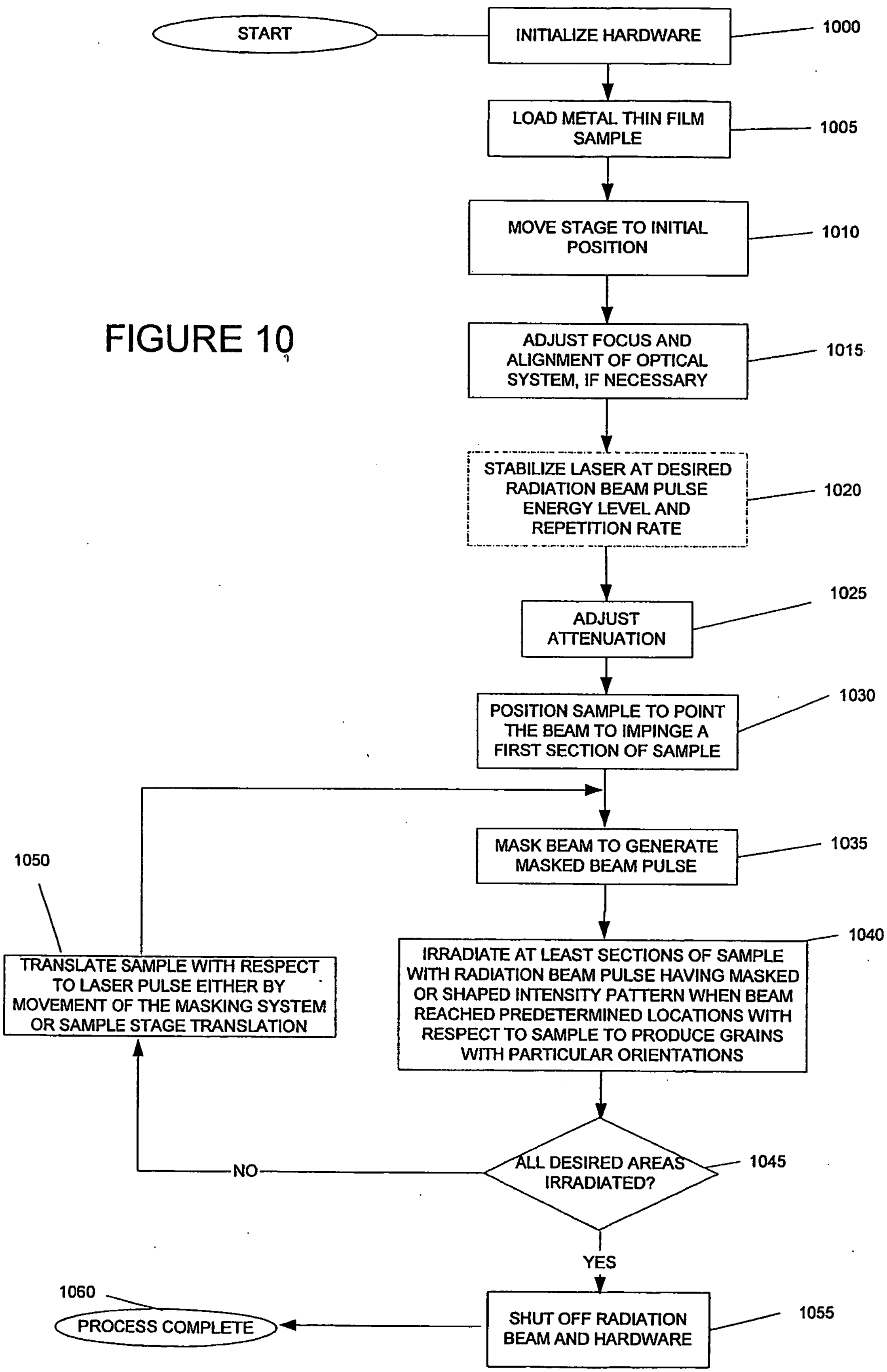

START
INITIALIZE HARDWARE
1000
LOAD METAL THIN FILM SAMPLE
1005
MOVE STAGE TO INITIAL POSITION
1010
ADJUST FOCUS AND ALIGNMENT OF OPTICAL SYSTEM, IF NECESSARY
1015
STABILIZE LASER AT DESIRED RADIATION BEAM PULSE ENERGY LEVEL AND REPETITION RATE
1020
ADJUST ATTENUATION
1025
POSITION SAMPLE TO POINT THE BEAM TO IMPINGE A FIRST SECTION OF SAMPLE
1030
MASK BEAM TO GENERATE MASKED BEAM PULSE
1035
IRRADIATE AT LEAST SECTIONS OF SAMPLE WITH RADIATION BEAM PULSE HAVING MASKED OR SHAPED INTENSITY PATTERN WHEN BEAM REACHED PREDETERMINED LOCATIONS WITH RESPECT TO SAMPLE TO PRODUCE GRAINS WITH PARTICULAR ORIENTATIONS
1040
ALL DESIRED AREAS IRRADIATED?
1045
NO
1050
TRANSLATE SAMPLE WITH RESPECT TO LASER PULSE EITHER BY MOVEMENT OF THE MASKING SYSTEM OR SAMPLE STAGE TRANSLATION
YES
SHUT OFF RADIATION BEAM AND HARDWARE
1055
PROCESS COMPLETE
1060

FIGURE 10